Appendix B

Emissions Inventory Methodology

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I. EMISSIONS INVENTORY DEVELOPMENT FOR CARGO HANDLING EQUIPMENT

A. Overview

Cargo handling equipment can be a significant source of diesel particulate matter (PM) emissions in communities near ports and intermodal rail facilities. To reduce diesel particulate matter (PM) emissions in these communities CARB passed a regulation requiring reductions in emissions from cargo handling equipment. With proposed amendments to that regulation staff is updating the inventory with a wealth of new information collected since 2005. These new sources of information include the regulatory reporting data which provides an accounting of all the cargo handling equipment (CHE) in the state including their model year, horsepower and activity. In addition, the Ports and Los Angeles and Long Beach have been conducting annual emissions inventories, and a number of the major rail yards and other ports in the state have completed individual emissions inventories. The methodology discussed here reflects updated population and activity, the impact of the recession on growth, and engine load. Emissions estimates were developed for six equipment classes associated with California's 14 ports 16 and intermodal rail yards. The updated inventory and emissions model, Cargo Handling Emissions Inventory Model, or CHEI, and the CHEI Working Files are posted on ARB's web site at http://www.arb.ca.gov/ports/cargo/cheamd2011.htm. (ARB, 2011f), (ARB,2011o)

B. Methodology for Estimating Emissions

The emissions from each type of equipment covered by the CHE regulation are calculated using the following equation:

Emissions = Pop * HP * LF * Activity * EF

Where:

Pop =	Equipment population
HP =	Maximum rated horsepower (hp)
LF =	Load factor
Activity =	Activity or annual operation (hr/yr)
EF =	Emission factor (g/hp-hr)

The equation above is applied to each piece of equipment, and the results summed to provide the emissions inventory. To estimate emissions in future years, staff projects a baseline population of vehicles into the future by modeling turnover and purchasing characteristics. These projections are modeled in a Microsoft Access database that projects future populations and emissions based on location-specific characteristics and behavior, economic forecasts, and ARB's regulatory requirements. This forecasting module is described in detail in chapter III of this appendix. The baseline inventory and the inputs to the equation above are described in section I.C below.

C. Emissions Inventory Inputs

1. Population

After the CHE rule was adopted in December, 2005, the regulation required all ports and rail yards with applicable vehicles to submit equipment inventories to ARB by January 31, 2007. (ARB, 2005c) The reporting forms required information such as vehicle make, model and serial number, and also usage characteristics such as hours used and average load factor during operation. These reports provided a new inventory of equipment for 2006 that serves as a baseline population for the updated inventory model.

The equipment population estimated for the original inventory developed in 2005 was based on a survey of ports and rail yards that ARB distributed in December, 2004 and a separate survey in 2001 and 2002 from the Port of Los Angeles and Port of Long Beach. (ARB, 2005b) The equipment population at the ports of Los Angeles and Long Beach represent over half of the population of cargo handling equipment in California. The combined surveys provided information on approximately 2,000 pieces of equipment, and the results were scaled upwards to estimate the total population of equipment in the state. This updated inventory is based on regulatory reporting data that accounts for all equipment in the state and therefore requires no scaling. ARB received equipment reports from 72 companies that operate at the 14 ports and 16 rail yards covered by the regulation. Table I-1 details the count of equipment reported by facility.

Table I-1: Population of Equipment by Facility

Location	Port/Rail	Population
Port of Los Angeles	P	1424
Port of Long Beach	P	1307
Port of Oakland	P	600
BNSF Los Angeles	R	274
Port of Stockton	P	145
Port of Hueneme	P	96
UPRR ICTF	R	86
BNSF San Bernardino	R	83

Location	Port/Rail	Population
San Diego Port & Railyard	P	66
Port of San Francisco	P	61
UPRR LA/Commerce	R	51
Port of Richmond	P	48
UPRR Oakland	R	35
BNSF Stockton	R	33
UPRR LATC	R	29
Port of Sacramento	P	28
BNSF Oakland	R	26
UPRR Lathrop	R	23
BNSF Commerce	R	22
UPRR City of Industry	R	20
Port of Redwood City	P	20
BNSF Fresno	R	9
Other Bay Area Ports & Railyards	P	8
BNSF Richmond	R	4
Port of Humboldt Bay	P	19
Total		**4517**

Table I-2 and Table I-3 show the combined population of equipment in ports and rail yards, respectively, and compares the totals against the original inventory population estimates for calendar year 2006.

Table I-2: Calendar Year 2006 Equipment Population for All Ports

Equipment Type	Original Inventory	Updated Inventory
Yard Tractor	2115	1861
Forklift	461	712
Container Handling Equipment	529	500
Crane	278 (All Cranes)	253 (RTG Only)
Construction Equipment	134	192
Other General Industrial Equipment	41	149
Total	**3558**	**3667**

Table I-3: Equipment Population for All Rail Yards

Equipment Type	Original Inventory	Updated Inventory
Yard Tractor	326	507
Crane	82 (All Cranes)	89 (RTG Only)
Forklift	24	66
Container Handling Equipment	30	25
Other General Industrial Equipment	5	15
Construction Equipment	1	3
Total	**468**	**705**

As shown in the preceding tables, the updated population for ports is very close to the original inventory estimates, only 2 percent higher overall. The population for rail yards, however, is 51 percent higher than the original inventory.

This new data provided not only an updated count of equipment, but also allowed staff to improve the inventory with updated location-specific characteristics, such as equipment age. Table I-4 compares the updated average age of equipment based on the reporting data against the averages age from the original inventory. The data shown for the original inventory below is the averages ages in 2006. Because the baseline for the original inventory was calendar year 2004, the averages in the table are shown after the impact of two years of attrition predicted by the original inventory model. This comparison is useful in showing the difference in the expected average age of equipment in the original inventory and the average ages from the reporting data. The significant difference seen in expected average and the average age reported to ARB not only impacts the baseline population, but also lead to revised projections of turnover and vehicle purchasing that more closely model real world conditions.

Table I-4: Average Equipment Age by Type in Calendar Year 2006

Equipment Type	Original Inventory	Updated Inventory
Yard Tractor	3.6	4.6
Forklift	4.1	12.7
Container Handling Equipment	5.2	5.9
Crane	7	6.7 (RTG Only)
Construction Equipment	5.4	13.6
Other General Industrial Equipment	4.6	13.1
Total	**4.2**	**7.1**

Overall, the updated inventory demonstrates a minor increase in overall population, but a shift to a significantly older average vehicle age.

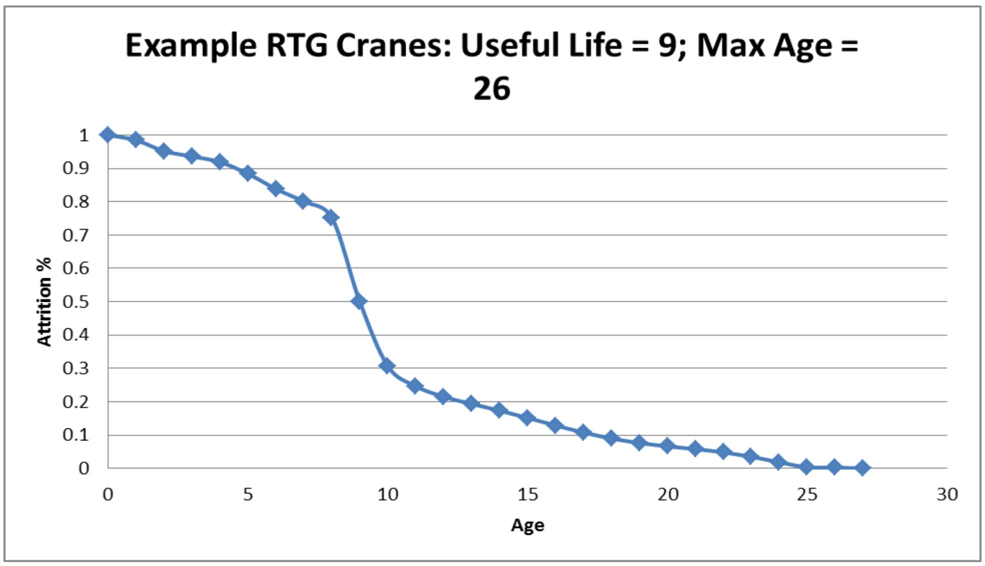
2. Turnover

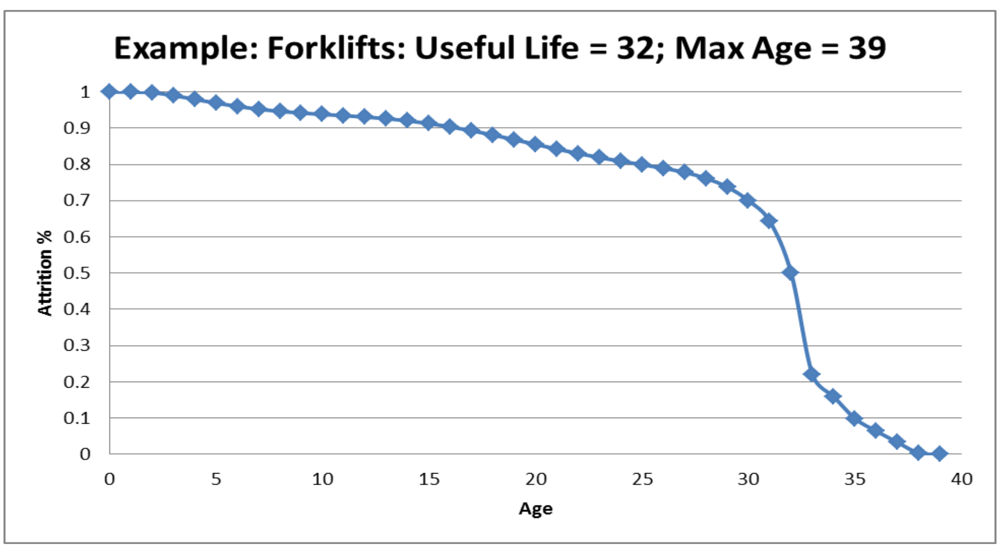
Turnover is a function that describes the relationship between equipment age and the proportion of equipment that has been removed from the port or rail yard fleet. These vehicles may leave a specific port/rail yard because of scrappage or because they are being sold to another fleet. The function is expressed in terms of a fraction of vehicles by age that remains in the population. The average lifetime varies by the type of equipment and the location. For this updated inventory staff relied on the turnover rate curves as defined by U.S. Environmental Protection Agency (U.S. EPA). (USEPA, 2005) U.S. EPA provides equations for which the user defines the useful life and maximum age of the equipment. Useful life is defined as the age where 50% of the vehicles have been turned over and the maximum life is the age at which all the vehicles have left the specific port or rail yard fleet. The application of these turnover functions was tailored to align with our understanding of the useful life information included in the reporting data.

In order to reflect location-specific turnover characteristics staff developed useful life and maximum life inputs based on groups of fleets with similar average age equipment. For example, all yard tractor at ports and rail yards with an average age around 5 years follow the same turnover trends whereas yard tractor fleets with an average around 10 years follow their own turnover trend. This way, smaller fleets which are difficult to model can follow the trends of similarly-aged larger ones. The assumption is that equipment with similar averge age will have the same turnover rates. The categorizations for these groupings can be found in Appendix A.

Turnover rates follow a traditional s-curve, but the shape of the curve is defined by the useful life and maximum life. Based on the age distributions developed from the grouped data in the table above staff identified the useful life as 1.5 times the average age of the equipment. The maximum age was defined as the 98th percentile of the age distribution. The following graphs are examples of the s-curves for RTG cranes with an average age of 6 and forklifts with an average age of 21. As you can see for this example location, RTG cranes are generally turned over by age 10. In the other example location, forklifts are maintained until almost 35 years old.

Figure I-1: Example Turnover Rates for Cranes and Forklifts





Turnover Curve Development

The turnover functions, or s-curve, developed for this updated inventory are specific to individual locations and equipment type characteristics and were developed in three steps: (1) Group similar fleets into the same category; (2) Develop a Business As Usual (BAU) age distribution; (3) Stretch or compress the curve so turnover models the BAU distribution. The result is that locations with a similar average age will follow the turnover rates.

(1) Group similar fleets into the same category

Since some equipment types at ports and rail yards have small populations, staff grouped locations with similar characteristics together. Different equipment types, however, were never modeled using the same turnover rates since the data shows that the different CHE equipment types are too unique to have the same turnover assumptions. Locations that were grouped together were based on average vehicle age into a (L)ow, (M)edium, (H)igh, or (O)ver-high category (see Appendix A). For example, all the equipment given a 'High' average age designation are used to develop the same BAU age distribution, which will be discussed in more detail later.

(2) Develop a Business As Usual (BAU) age distribution

Once the categories have been established, many different sources of population data are compiled to develop an age distribution that represents business as usual in the absence of the regulation. To develop this BAU age distribution staff relied on the regulatory reporting database (ARB, 2005c), the annual inventories for the Port of Los Angeles/Port of Long Beach (Starcrest, 2010a) (Starcrest 2010b), the 2005 Port of Oakland inventory (Environ, 2008), the 2005 Railyard Health Risk Assessment inventories (ARB, 2008), and ARB's 2004 CHE equipment survey. (ARB, 2005b) The BAU age distributions were developed from a polynomial fit of the data. These curves are then used for turnover and purchasing and are unique to each *category* of equipment type shown in Appendix A.

(3) Stretch or compress the curve so turnover models the BAU distribution

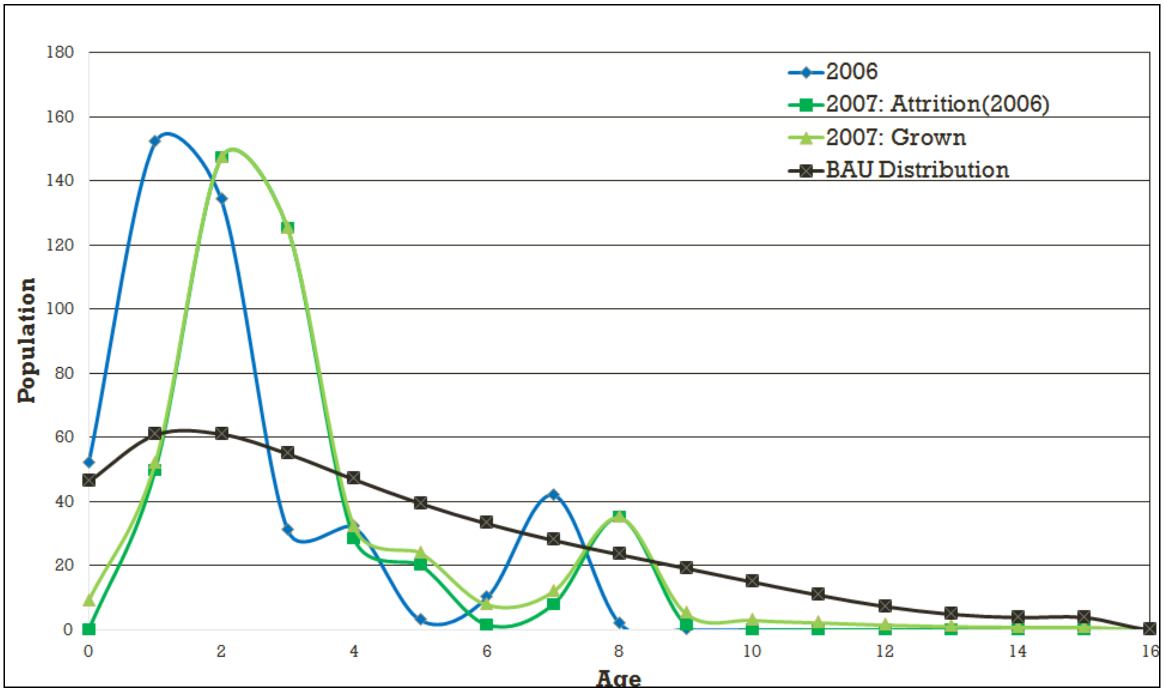
The useful life of the turnover function was determined to be at 1.5 times the average age of the BAU distribution because this is where the distributions had a significant drop off in population. It was also observed that the model preserved BAU well at this useful life. The max life was placed at the 98^{th} percentile of the population data. Any equipment that was reported older than this had a very large standard deviation from what was normal; increasing the max age to include these outliers would result in a population much older than anticipated.

3. Purchasing

The other component of equipment turnover is purchasing. Purchasing is very specific to each port and rail yard. Some locations maintain vehicles that are very young and thus purchase young vehicles while other maintain older equipment and thus purchase older vehicles. Since the updated inventory developed for these amendments is location-group and equipment-specific purchasing behavior was necessary at this level of detail.

In order to establish purchasing habits for each location-group an historically average baseline age distribution was developed. This distribution, hereby referred to as the ‘business as usual age distribution’ was estimated from 2001-2007 historical equipment inventory data (see Turnover Curve Development above). This age distribution represents the age distribution of the equipment at that location in the absence of the rule and recession. This distribution was used as a target age distribution in projecting fleet turnover in the absence of the recession and regulation. The distribution of vehicle purchases was determined by the business as usual age distribution for the baseline inventory. New vehicle purchases under the rule inventory were dictated by the rule requirements. The example for yard trucks below helps to illustrate the concept. The blue line is the 2006 age distribution. After attrition is applied the resulting population (the dark green line with boxes) is a year older and smaller as a result of vehicles leaving the fleet (turnover). To determine the age of vehicles purchased the business as usual (BAU) age distribution is used to distribute new vehicle purchases among the ages where the attrited 2007 population is below the business as usual population. These purchases are added to the 2007 attrited population resulting in the 2007 grown population (light green line with triangles). In reality this adjustment takes into account both purchasing and necessary modifications to turnover rates where the estimated turnover assumptions don’t exactly match fleet behavior. Over time the base year age distribution will move towards resembling the business as usual age distribution.

Figure I-2: Purchasing Example for 2006 to 2007 population change



Purchasing Distribution

After turnover has been applied to a given population purchasing is distributed among model years to eventually reestablish the BAU age distribution. These purchases enter the fleet at a specific location as a result of turnover and growth and are accomplished in two steps: (1) Calculating the number of total vehicles that need to be purchased; and (2) Distributing the purchases so the BAU distribution is eventually reestablished.

(1) Calculating the number of total vehicles that need to be purchased

The total number of vehicles that need to be purchased is a function of the number retired and the expected growth from one year to the next. The growth of a population is calculated by multiplying the count of equipment before retirement by a growth factor (see '6. Growth & Recovery' for details on growth factors).

(2) Distributing the results so the BAU distribution is reestablished into the future

The total number of vehicles purchased is distributed among model years so that each age bin gets relatively closer to the BAU distribution. If an age bin is already above the BAU distribution there is no purchasing for that bin. The percentage of vehicles given to each bin is chosen so that each gets proportionally closer to BAU. For example, if 3 vehicles are to be distributed between age 3 and age 5 which have populations of 8 and 10 respectively, and BAU has these populations both at 12 vehicles, then the age 3 bin gets 2 vehicles and age 10 bin gets 1 vehicle.

4. Engine Load Factor

Engine load is the average operational level of an engine in a given application as a fraction or percentage of the engine manufacturer's maximum rated horsepower. Since emissions are directly proportional to engine horsepower, load factors are used in the inventory calculations to adjust the maximum rated horsepower to normal operating levels.

In 2006 the Port of Los Angeles and Port of Long Beach conducted a study of engine load for yard trucks. (Starcrest, 2008a) (Starcrest, 2008b) In 2009, a similar study was performed for cranes operated at both ports. (Starcrest, 2010a) (Starcrest, 2010b) Both studies demonstrated that the load factor used in the original inventory was too high. The result was that the load factor for yard trucks was reduced to 0.39, and to 0.2 for RTG cranes. Load factors for excavators were updated from 0.57 to 0.55, as excavators were combined with the 'Tractor/Loader/Backhoe' category into the 'Construction Equipment' category of CHE, with a shared load factor of 0.55. Table I-5 below displays the load factor in the original inventory and the updated load factors.

In the original inventory, the load factors for each equipment type were taken from the ARB OFFROAD model. (ARB, 2007) For all other CHE equipment types except yard trucks and RTG cranes this remains the best available data.

Table I-5: Engine Load Factors

Equipment	Original Inventory	Updated Inventory
Yard Tractor	0.65	0.39
RTG Crane	0.43	0.2
Excavator	0.57	0.55
Forklift	0.30	0.30
Material Handling Equip	0.59	0.59
Other General Industrial Equip	0.51	0.51
Tractor/Loader/Backhoe	0.55	0.55

5. Activity

Background

The activity or annual operation of off-road equipment is measured in annual average hours of use and varies by equipment type and age. Since the original rulemaking a number of new data sources have become available. These data show, Figures I-3 and I-4 below, that there are differences in activity by location as well as differences in activity as the equipment ages. These differences have been analyzed and taken into account in this updated inventory.

Activity profiles for CHE in the original rulemaking inventory were estimated using data from a CARB survey of ports and rail yards in 2004. (ARB, 2004) Activity data were collected from 69 owner/operators statewide and captured operating hours for approximately 2,000 pieces of equipment. These data were aggregated to represent typical activity of specific equipment types at ports and rail yards as shown in Table I-6.

Table I-6: Activity Values for CHE in Original Inventory

	Annual Hours	
Equipment Type	**Port**	**Rail Yard**
Crane	1371	1632
Excavator	2222	1162
Forklift	1098	803
Material Handling Equip	2388	2388
Other General Industrial Equip	693	1632
Sweeper/Scrubber	872	872
Tractor/Loader/Backhoe	755	755
Yard Tractor	2536	1289

Figure I-3: Yard Truck Annual Hours by Location (2006)

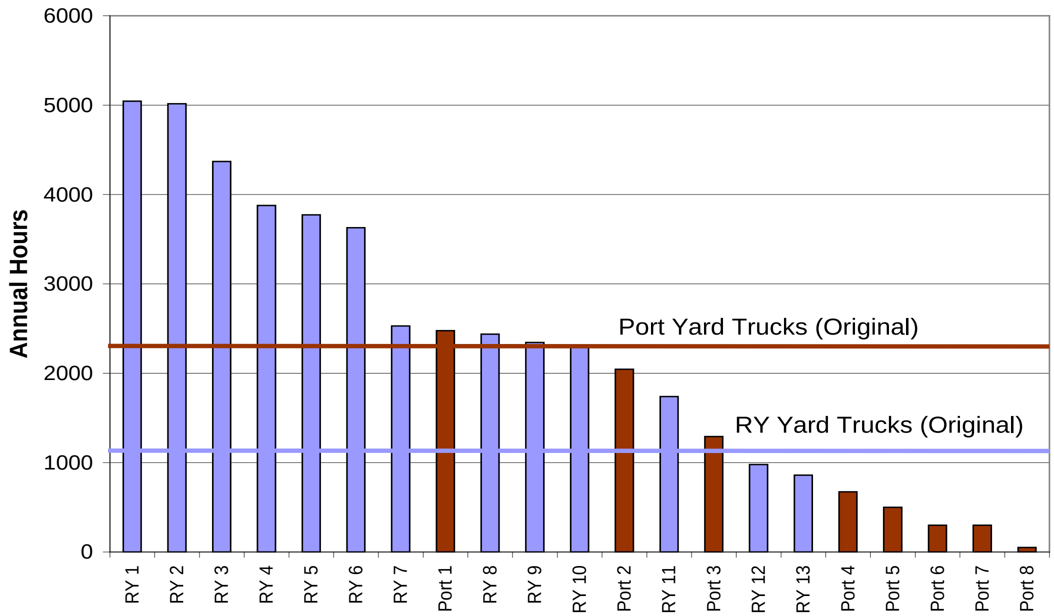
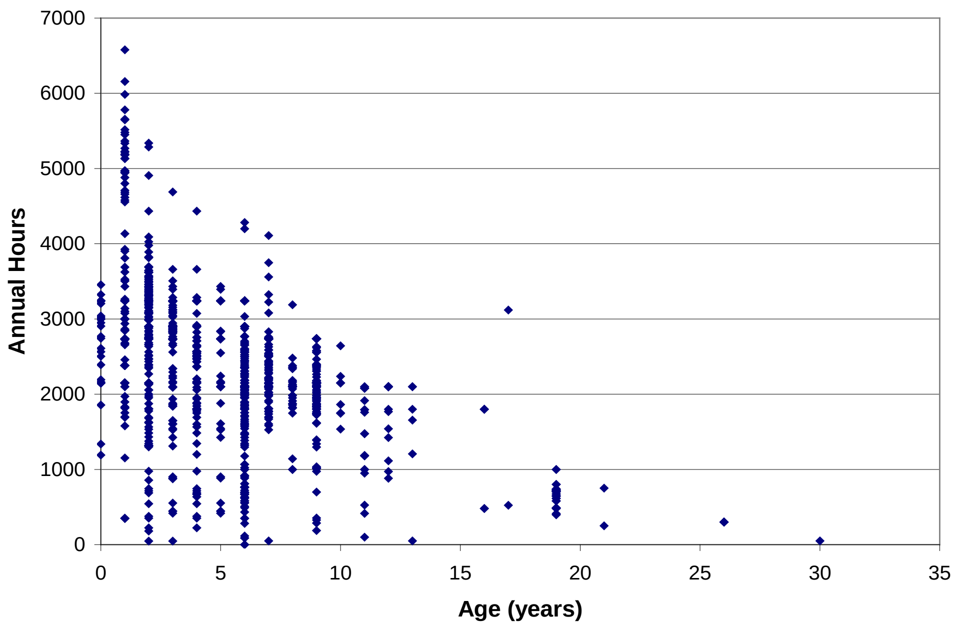


Figure I-4: Activity by Age for Yard Tractors in a California Port



Data Sources

Since the original CHE emissions inventory was developed in 2005, new data sources for CHE activity have become available. These new data sources are the basis for the activity values in the new emissions inventory and are described below.

CHE Regulation Reporting Data: As part of the 2006 CHE regulation, fleet owners and operators of CHE were required to submit information to CARB regarding equipment populations and hours of use. (ARB, 2005) Data were collected for over 4,000 pieces of equipment.

Rail Yard Health Risk Assessments (HRA): As part of the rail yard emission reduction program, health risk assessments were initiated in 2005 to determine the relative risk of exposure to diesel particulate matter in the proximity of 17 intermodal rail yards. As part of the assessment, activity data were collected for over 400 pieces of cargo handling equipment. (ARB, 2008)

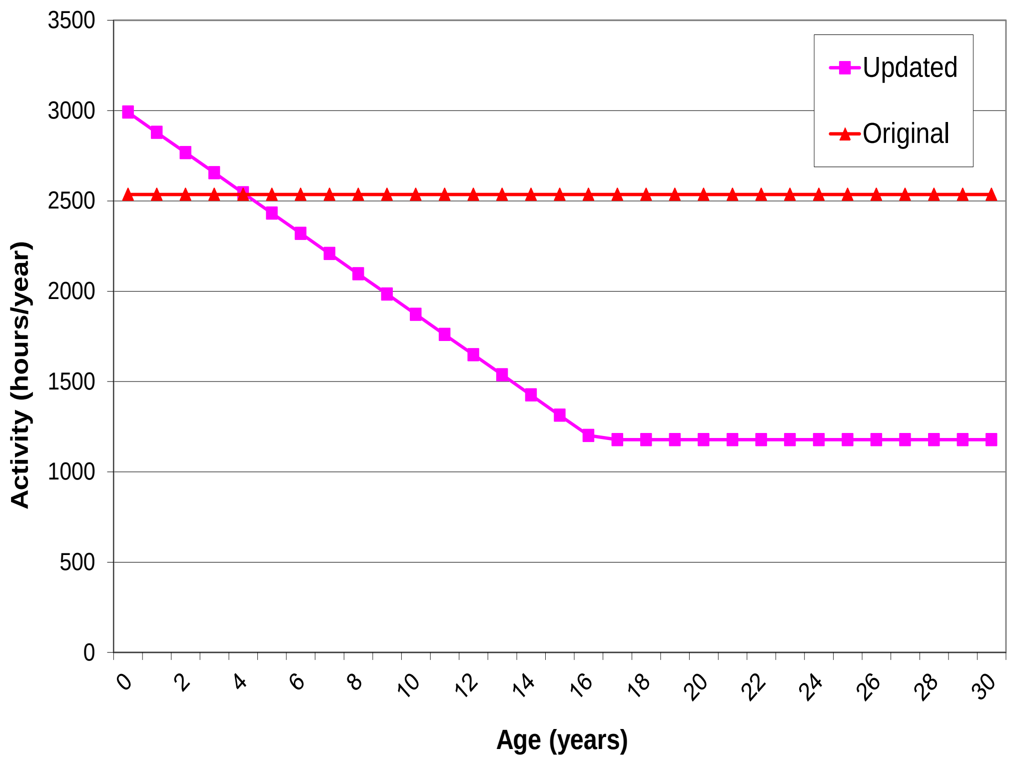
Starcrest/ENVIRON Port Emissions Inventories: CHE emissions inventories for the past several years have previously been developed by the Starcrest consulting group for the Ports of Los Angeles, Long Beach and San Diego. In addition, the ENVIRON consulting group developed a CHE emissions inventory for the Port of Oakland in 2005. (Environ, 2008) As part of the emission inventory development process, activity data for several thousand pieces of equipment were collected at each of these ports. For the current inventory, calendar year 2006 activity data from these consulting reports were used as new sources of activity data. (Starcrest, 2008a) (Starcrest, 2008b) (Starcrest, 2008c)

Methodology

Depending on the equipment type and location, staff used either one of two methods to develop activity profiles. For those locations where use was determined to be a function of age an appropriate activity profile was developed. For those locations where activity was not determined to be a function of age an average activity was employed. These two methods are described below.

Trend Method: For this method, staff identified those equipment types displaying a significant decreasing trend in activity by age. Significant decreasing trends were identified by plotting all the available activity data described previously for each equipment type and location and performing a linear regression. The trend was considered significant it the slope was negative (i.e. decreasing activity by age) and contained a t-value greater than the critical t value at the 95% confidence level. In these cases, the trend line equation was used to calculate the activity by age profile for the specific equipment type and location. In order to ensure that the activity values never became zero due to the decreasing trend line, staff determined an inflection point (i.e. age) where activity ceased to decrease and became constant. The first step was to identify the age that represented twice the average age of the equipment types in a given location. Staff then calculated the average activity of all available data for the specific equipment type above this age. The point at which the decreasing trend line intersected this activity value was then used to define the activity by age profile for the specific equipment type and location. Figure I-5 shows an example activity by age profile for yard tractors at the Port of Los Angeles using the new methodology as well as the activity by age profile in the previous inventory.

Figure I-5: Activity by Age Profile for POLA Yard Tractors



Average Method: For those equipment types where there was no significant trend, the average of all activity values was assigned to specific equipment type and location. In other words, one activity value was assigned to the equipment type regardless of how old the equipment was.

Results

Using the above methodologies, staff calculated the overall average hours by equipment type. The results are shown in Tables I-7 and I-8 for ports and rail yards, respectively. For comparison purposes, the average activity values used in the previous emissions inventory are also shown.

Table I-7: Average Activity Values at Ports

Equipment Type	Original Inventory (for 2006) (hours/year)	Updated Inventory (2006) (hours/year)
Construction Equipment	1,084	1,497
Container Handling Equipment	2,388	1,884
Forklift	1,098	701
Other General Industrial Equipment	693	1,265
RTG Crane	1,371	1,574
Yard Tractor	2,536	2,020
All Equipment	**2,159**	**1,656**

Table I-8: Average Activity Values at Rail Yards

Equipment Type	Original Inventory (for 2006) (hours/year)	Updated Inventory (2006) (hours/year)
Construction Equipment	755	141
Container Handling Equipment	2,388	1,705
Forklift	803	2,234
Other General Industrial Equipment	1,632	1,024
RTG Crane	1,632	3,398
Yard Tractor	1,289	4,627

6. Growth & Recovery

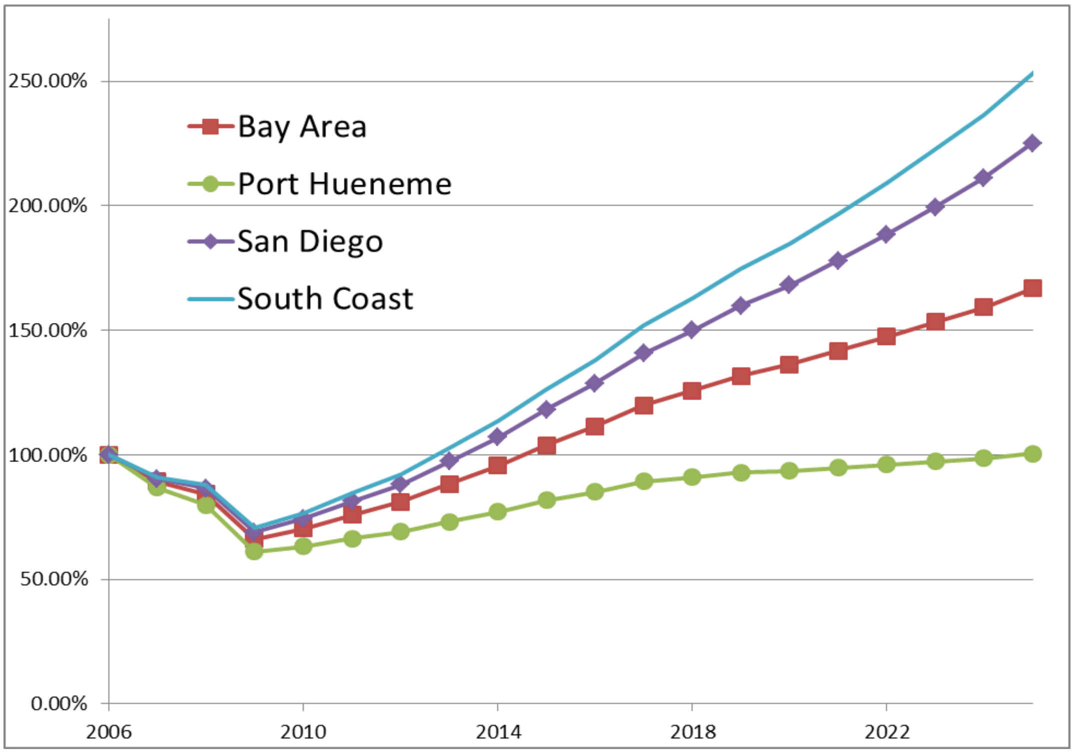
The growth factors used to estimate cargo handling equipment emissions in future years was based on growth factors from ARB's Ocean-Going vessel (OGV) inventory for container, bulk, general and reefers vessels. Information on these growth factors can be found in the OGV technical appendix. (ARB, 2011l)

The economic recession that officially started in December of 2007 and ended in June 2009 was the most severe since the Great Depression, and had a severe impact on industries throughout California. To forecast activity following the recession, three recovery scenarios were considered to encompass the possible rates of growth of "fast", "slow", and "average". The fast recovery scenario assumes that total activity would return to projected historically average levels in 2017 and then grow at the historical average rate. A return to trend by 2017 was based on the Congressional Budget Office forecast which indicated that real gross domestic product at a nationwide level will converge with potential gross domestic product trends no later than 2015. This forecast was modified with the assumption that California's recovery will lag the nation by several years, yielding the 2017 recovery date assumed for the fast recovery scenario. For the slow recovery scenario, staff assumed that activity would be permanently depressed relative to historical levels, but continue to grow at historical rates. The average scenario is the average of the fast and slow scenarios.

The impact of the recession was estimated from port call and TEU data. Given the uncertainty in forecasting emissions after such a deep recession, staff relied on the average recovery scenario. This scenario, for the years of interest for these regulatory amendments, is also supported by the most recent San Pedro Bay forecasts. The methodology is consistent with the In-Use On-Road and Off-Road rules.

The growth rates were aggregated according to ports and rail yards in the South Coast, San Diego, Bay Area, Hueneme and the North Coast and are shown in Figure I-6 below and in Appendix B.

Figure I-6: Growth Factors



Economic Recovery Factors

The age distribution of off-road diesel equipment has important implications for the emissions inventory. In general, an older vehicle will produce more emissions than a newer vehicle operating under the same conditions. In light of the economic recession, it is important to assess the impacts of the economy on sales of new off-road diesel equipment. Depending on the state of the economy in a given calendar year, one of several scenarios will occur regarding the sales of the new equipment. These scenarios will impact the relative proportion of the new model year equipment in the age distribution. These scenarios include:

- **New equipment sales are higher than expected equipment sales**. The proportion of the new model year equipment pieces in the age distribution will therefore be *higher* than the proportion in a baseline (no impact) age distribution.

- **New equipment sales are lower than expected equipment sales**. The proportion of the new model year equipment pieces in the age distribution will therefore be *lower* than the proportion in a baseline (no impact) age distribution.
- **New equipment sales are equal to expected equipment sales**. The proportion of the new model year equipment pieces will therefore be *equal* to the proportion in a baseline (no impact) age distribution age distribution.

The Off-Road In-Use Equipment Regulation emissions inventory incorporated these impacts by estimating the impact of new off-road diesel equipment sales on future age distributions. Staff did this by developing economic recovery factors, which are a measure of how much a port or rail yard's fleet ages over time. During times of economic recession, less new equipment is purchased and the average age of the fleet increases. As a result the average age of a given fleet increases comared to the base year. The economic recovery factors define the fleet average age in the future.

The method, however, relies on equipment sales and economic surrogate information such as gross domestic product (GDP). (ARB, 2010b) Without equipment sales information for CHE staff relied on the same methods used for the Off-Road In-Use Equipment Regulation. (ARB, 2010b) Since construction equipment sales were proportional to GDP it was assumed the CHE sales would follow trends in TEU throughput at the ports. Staff utilized the economic recovery factors developed for the Construction and Mining Category and dampened them according to the relative difference in the impacts of the recession on the industry. For example, the Ports of Los Angeles and Long Beach (LA/LB) saw a 25% drop in TEU while the construction industry experienced nearly a 50% drop in GDP. Therefore the economic recovery factors were halved to account for this difference in recessionary impacts. This is evident in Figure I-7 which shows both the LA/LB and Off-Road recovery factors. The LA/LB factors are about half of the Off-Road factors.

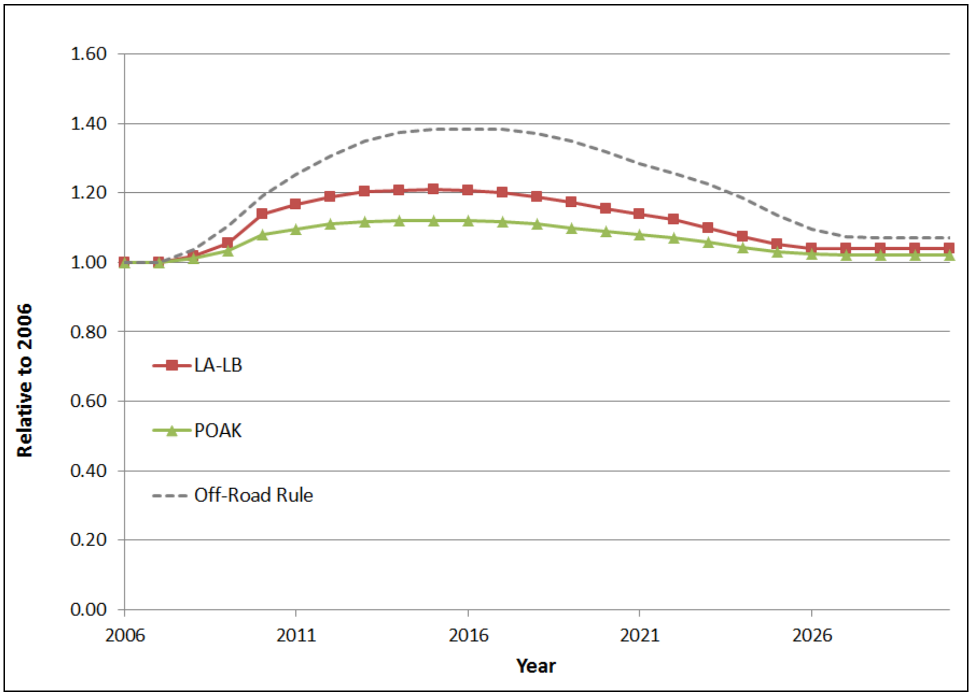
The Table I-9 shows the impacts of the recession for the combined ports of Los Angeles (POLA, 2010) and Long Beach (POLB, 2010), the Port of Oakland (POAK, 2010), and the Port of San Diego (AAPA, 2010):

Table I-9: Impacts of the Recession on TEU

Port	TEU Change 2006-2009
LA+LB	25%
POAK	14%
POSD	7%

For all ports the impact of the recession is less than that of the construction industry therefore the economic recovery factors for all these locations will be dampened relative to construction. The figure below (I-7) shows the economic recovery factors for these ports relative to the construction industry factors. Only the ports of Los Angeles, Long Beach, Oakland and San Diego were included in this assessment since they comprise the vast majority of the equipment in California.

Figure I-7: Impacts of the Recession Fleet Average Age



7. Emission Factors and Deterioration Rates

Emission factors are composed of zero-hour emission rates and deterioration rates. In the original inventory deteriorated emission factors were calculated with deterioration factors and useful life assumptions. This inventory relies on emission factors and deterioration rates from OFFROAD2007. Deteriorated emission factors can be calculated with the following equation:

EF = Zh + dr * CHrs

Where:
EF = Emission factor (g/bhp-hr)
Zh = Zero-hour emission rate when the equipment is new (g/bhp-hr)
Dr = Deterioration rate or the increase in zero-hour emissions as the equipment is used (g/bhp-hr2)
CHrs = Cumulative hours or total number of hours accumulated on the equipment; maximum value is equal to 12,000 hours

The diesel emission factors in the model are in grams per brake horsepower-hour and vary by fuel type, horsepower, and model year. To estimate fuel consumption, an emission factor is replaced with a brake-specific fuel consumption (BSFC) value (lb/hp-hr). BSFC values are used from the U.S. EPA NONROAD model. (USEPA, 2004)

<u>Emission Factors</u>

Emission factors for future years were based on the OFFROAD model which incorporates the impacts of new engine standards (Tier 3 and 4) for each year and horsepower range. The emission factors reflect any phase-in of emission standards allowed by the regulations establishing the new engine standards. Because the regulation is based on specific Tier requirements the OFFROAD2007 emission factors were updated to align with U.S. EPA horsepower bins.

Deterioration rates are in units of $g/hp\text{-}hr^2$ (grams per brake horsepower-hour-hour) and are defined as the change in emissions as a function of usage. These are based on the deterioration rates of on-highway diesel-powered engines with similar horsepower ratings. The rate of emissions changes over time as a result of wear on various parts of an engine due to use. It is assumed that at some point during the life of an equipment its engine would be rebuilt back to the standard of that particular emissions tier (varies by model year of the engine). As a result cumulative hours in the equation above is capped. In this inventory cumulative hours was capped at 12,000 hours, consistent with the Off-Road In Use Equipment Regulation, since no data was specifically available for CHE.

Emission factors for on-road engines in were based on a study that tested both on-road and off-road engines in yard tractors. (ARB, 2006) The factors in Table I-10 are applied to off-road emission factors to convert them to on-road emission factors.

Table I-10: On-Road Conversion Factors

MY	HP Bin	HC	CO	NO_x	PM
2003	175	0.33	1	0.44	0.70
2004	175	0.33	1	0.44	0.70
2005	175	0.33	1	0.44	0.70
2006	175	0.33	1	0.44	0.70
2007	175	0.33	1	0.69	0.70
2008	175	0.33	1	0.42	0.07
2009	175	0.33	1	0.42	0.07
2010	175	0.33	1	0.42	0.07
2011	175	0.33	1	0.07	0.07
2012	175	0.33	1	0.13	0.67
2013	175	0.33	1	0.13	0.67
2014	175	0.33	1	0.13	0.67
2015+	175	0.33	1	0.67	0.67
2003	300	0.33	1	0.44	0.70
2004	300	0.33	1	0.44	0.70
2005	300	0.33	1	0.44	0.70
2006	300	0.33	1	0.69	0.70
2007	300	0.33	1	0.42	0.07
2008	300	0.33	1	0.42	0.07
2009	300	0.33	1	0.42	0.07
2010	300	0.33	1	0.07	0.07
2011	300	0.33	1	0.13	0.67
2012	300	0.33	1	0.13	0.67
2013	300	0.33	1	0.13	0.67
2014+	300	0.33	1	0.67	0.67
2003	600	0.33	1	0.44	0.70
2004	600	0.33	1	0.44	0.70
2005	600	0.33	1	0.44	0.70
2006	600	0.33	1	0.69	0.70
2007	600	0.33	1	0.42	0.07
2008	600	0.33	1	0.42	0.07
2009	600	0.33	1	0.42	0.07
2010	600	0.33	1	0.07	0.07
2011	600	0.33	1	0.13	0.67
2012	600	0.33	1	0.13	0.67
2013	600	0.33	1	0.13	0.67
2014+	600	0.33	1	0.67	0.67

Emission Controls

A number of the state's deep-water ports have implemented cargo handling equipment emission reduction strategies using state funding, such as the Carl Moyer Program, or through port mechanisms. In addition the regulation requires the use of additional emission controls. The emissions inventory reflects the population of emission controlled equipment resulting from these programs. The reductions by emission control are consistent with the original inventory and are presented in Table I-11. These reductions are applied to the base emission rates. In some cases, such as O_2 Diesel, there are emissions disbenefits.

Table I-11: Emission Control Emissions Reductions (percent reduction)

Engine changes	HC	CO	NO_x	PM
DOC	0.7	0.7	0	0.3
DOC + O_2Diesel	0.48	0.73	0.02	0.44
DPF	0	0	0	0.85
O_2 Diesel	-0.75	-0.1	0.02	0.2

8. Fuel Correction Factors

California implemented diesel fuel regulations in 1993, which lowered the limits of aromatic compounds and the sulfur content of fuel marketed in California. The fuel correction factors (FCF) used in the emissions inventory model are dimensionless multipliers applied to the basic exhaust emission rates that account for differences in the properties of certification fuels compared to those of commercially dispensed fuels. In instances where engines or vehicles are not required to certify, the FCFs reflect the impact in changes of dispensed fuel over time as refiners respond to changes in fuel specific regulations compared to the fuel used to obtain the test data. The FCFs used in the model were specific to horsepower group and model year and were based on data described in a 2005 OFFROAD Modeling Change Technical Memo. (ARB, 2005d)

II. EMISSIONS INVENTORY RESULTS

The emission inventory for cargo handling equipment includes total emissions for the locations identified in Table I-1. The data in Table II-1 summarizes the statewide inventory of oxides of nitrogen (NO_x) and diesel particulate matter (PM) for 2006 by equipment type. Combined yard trucks, container handling equipment (top picks, sides picks, etc.), and cranes are responsible for approximately 85 percent of the emissions for all pollutants.

Table II-1: Emissions by Equipment Type (tons/day)

Calendar Year	Equipment Type	NO_x	PM
2006	Construction Equipment	1.03	0.046
2006	Container Handling Equipment	3.06	0.094
2006	Forklift	0.56	0.032
2006	Other General Industrial Equipment	0.54	0.030
2006	RTG Crane	1.23	0.038
2006	Yard Tractor	6.98	0.298

Table II-2: Calendar Year 2006 Emissions by Air District (tons/day)

District	NO_x	PM
Bay Area AQMD	1.91	0.080
Yolo/Solano AQMD	0.02	0.001
San Diego APCD	0.07	0.003
San Joaquin Valley Unified APCD	0.30	0.016
South Coast AQMD	11.06	0.436
Ventura APCD	0.04	0.002
North Coast Unified AQMD	0.02	0.0009

Table II-3: Emissions Inventory Statewide (tons per day)

Calendar Year	PM (tons/day)			NO_x (tons/day)		
	Baseline	Rule	Amendments	Baseline	Rule	Amendments
2006	0.54	0.54	0.54	13.4	13.4	13.4
2011	0.35	0.18	0.18	8.0	5.9	5.9
2014	0.30	0.08	0.08	7.3	4.2	4.3
2020	0.20	0.08	0.06	4.7	3.2	3.1

Table II-4: Emissions Inventory for South Coast Air Basin (tons per day)

Calendar Year	PM (tons/day)			NO_x (tons/day)		
	Baseline	Rule	Amendments	Baseline	Rule	Amendments
2006	0.44	0.44	0.44	11.1	11.1	11.1
2011	0.28	0.15	0.15	6.6	4.9	4.9
2014	0.24	0.07	0.06	5.9	3.4	3.5
2020	0.15	0.06	0.05	3.7	2.6	2.5

Table II-5: Emissions Inventory for San Francisco Air Basin (tons per day)

Calendar Year	PM (tons/day)			NO_x (tons/day)		
	Baseline	Rule	Amendments	Baseline	Rule	Amendments
2006	0.08	0.08	0.08	1.9	1.9	1.9
2011	0.05	0.03	0.03	1.1	0.9	0.9
2014	0.05	0.01	0.01	1.1	0.7	0.7
2020	0.03	0.01	0.01	0.8	0.5	0.5

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Appendix A

Categorization of Similar Equipment		
Equipment	**Category**	**Location**
Construction Equipment	H	Port of Humboldt Bay
Construction Equipment	H	Port of Richmond
Construction Equipment	H	Port of Stockton
Construction Equipment	H	UPRR Oakland
Construction Equipment	L	BNSF Stockton
Construction Equipment	L	Other Bay Area Ports & Railyards
Construction Equipment	L	Port of Long Beach
Construction Equipment	L	Port of Redwood City
Construction Equipment	L	Port of Sacramento
Construction Equipment	L	Port of San Francisco
Construction Equipment	L	San Diego Port & Railyard
Construction Equipment	M	Port of Los Angeles
Construction Equipment	M	Port of Oakland
Container Handling Equipment	H	BNSF Fresno
Container Handling Equipment	H	BNSF Los Angeles
Container Handling Equipment	H	BNSF Oakland
Container Handling Equipment	H	BNSF San Bernardino
Container Handling Equipment	H	Port of Hueneme
Container Handling Equipment	H	Port of San Francisco
Container Handling Equipment	H	Port of Stockton
Container Handling Equipment	H	San Diego Port & Railyard
Container Handling Equipment	H	UPRR City of Industry
Container Handling Equipment	H	UPRR ICTF
Container Handling Equipment	H	UPRR LA/Commerce
Container Handling Equipment	H	UPRR LATC
Container Handling Equipment	H	UPRR Lathrop
Container Handling Equipment	L	BNSF Stockton
Container Handling Equipment	L	Port of Long Beach
Container Handling Equipment	L	Port of Los Angeles
Container Handling Equipment	L	Port of Oakland
Container Handling Equipment	L	UPRR Oakland
Forklift	H	Port of Hueneme
Forklift	H	Port of Oakland
Forklift	H	Port of Sacramento
Forklift	H	UPRR LA/Commerce
Forklift	L	BNSF Fresno
Forklift	L	BNSF Oakland

Categorization of Similar Equipment		
Equipment	Category	Location
Forklift	L	BNSF San Bernardino
Forklift	L	BNSF Stockton
Forklift	L	Other Bay Area Ports & Railyards
Forklift	L	Port of Redwood City
Forklift	L	UPRR City of Industry
Forklift	L	UPRR ICTF
Forklift	L	UPRR LATC
Forklift	L	UPRR Lathrop
Forklift	L	UPRR Oakland
Forklift	M	BNSF Los Angeles
Forklift	M	Port of Long Beach
Forklift	M	Port of Los Angeles
Forklift	M	Port of Stockton
Forklift	O	Port of Humboldt Bay
Forklift	O	Port of Richmond
Forklift	O	Port of San Francisco
Forklift	O	San Diego Port & Railyard
Other General Industrial Equipment	H	BNSF Los Angeles
Other General Industrial Equipment	H	Port of Hueneme
Other General Industrial Equipment	H	Port of Long Beach
Other General Industrial Equipment	H	Port of Oakland
Other General Industrial Equipment	H	Port of Redwood City
Other General Industrial Equipment	H	Port of Richmond
Other General Industrial Equipment	H	Port of Sacramento
Other General Industrial Equipment	H	Port of Stockton
Other General Industrial Equipment	H	UPRR ICTF
Other General Industrial Equipment	H	UPRR Lathrop
Other General Industrial Equipment	H	UPRR Oakland
Other General Industrial Equipment	L	BNSF Stockton
Other General Industrial Equipment	L	Port of Los Angeles
Other General Industrial Equipment	L	San Diego Port & Railyard
Other General Industrial Equipment	L	UPRR LA/Commerce
RTG Crane	H	BNSF Fresno
RTG Crane	H	BNSF Richmond
RTG Crane	H	Other Bay Area Ports & Railyards
RTG Crane	H	Port of Hueneme
RTG Crane	H	Port of Oakland
RTG Crane	H	UPRR City of Industry
RTG Crane	H	UPRR LA/Commerce
RTG Crane	L	BNSF Commerce

Categorization of Similar Equipment		
Equipment	Category	Location
RTG Crane	L	BNSF Los Angeles
RTG Crane	L	BNSF San Bernardino
RTG Crane	L	BNSF Stockton
RTG Crane	L	Port of Long Beach
RTG Crane	L	Port of Los Angeles
RTG Crane	L	UPRR ICTF
RTG Crane	L	UPRR LATC
RTG Crane	L	UPRR Lathrop
RTG Crane	L	UPRR Oakland
Yard Tractor	H	BNSF Fresno
Yard Tractor	H	BNSF Oakland
Yard Tractor	H	BNSF Richmond
Yard Tractor	H	BNSF San Bernardino
Yard Tractor	H	Other Bay Area Ports & Railyards
Yard Tractor	H	Port of Hueneme
Yard Tractor	H	Port of Humboldt Bay
Yard Tractor	H	Port of Long Beach
Yard Tractor	H	Port of Los Angeles
Yard Tractor	H	Port of Oakland
Yard Tractor	H	Port of Redwood City
Yard Tractor	H	Port of Sacramento
Yard Tractor	H	Port of San Francisco
Yard Tractor	H	Port of Stockton
Yard Tractor	H	San Diego Port & Railyard
Yard Tractor	H	UPRR LA/Commerce
Yard Tractor	L	BNSF Commerce
Yard Tractor	L	BNSF Los Angeles
Yard Tractor	L	BNSF Stockton
Yard Tractor	L	UPRR City of Industry
Yard Tractor	L	UPRR ICTF
Yard Tractor	L	UPRR LATC
Yard Tractor	L	UPRR Lathrop
Yard Tractor	L	UPRR Oakland

Appendix B Growth Rates:

Area	Year	**Growth Factor**
Bay Area	2000	0.73
Bay Area	2001	0.77
Bay Area	2002	0.82
Bay Area	2003	0.86
Bay Area	2004	0.90
Bay Area	2005	0.95
Bay Area	2006	1.00
Bay Area	2007	0.89
Bay Area	2008	0.84
Bay Area	2009	0.66
Bay Area	2010	0.70
Bay Area	2011	0.76
Bay Area	2012	0.81
Bay Area	2013	0.88
Bay Area	2014	0.96
Bay Area	2015	1.04
Bay Area	2016	1.11
Bay Area	2017	1.20
Bay Area	2018	1.26
Bay Area	2019	1.32
Bay Area	2020	1.36
Bay Area	2021	1.42
Bay Area	2022	1.47
Bay Area	2023	1.53
Bay Area	2024	1.59
Bay Area	2025	1.67
Bay Area	2026	1.73
Bay Area	2027	1.80
Bay Area	2028	1.82
Bay Area	2029	1.83
Bay Area	2030	1.82
Port Hueneme	2000	0.99
Port Hueneme	2001	0.99
Port Hueneme	2002	0.99
Port Hueneme	2003	0.99
Port Hueneme	2004	1.00
Port Hueneme	2005	1.00
Port Hueneme	2006	1.00

Port Hueneme	2007	0.87
Port Hueneme	2008	0.80
Port Hueneme	2009	0.61
Port Hueneme	2010	0.63
Port Hueneme	2011	0.66
Port Hueneme	2012	0.69
Port Hueneme	2013	0.73
Port Hueneme	2014	0.77
Port Hueneme	2015	0.82
Port Hueneme	2016	0.85
Port Hueneme	2017	0.89
Port Hueneme	2018	0.91
Port Hueneme	2019	0.93
Port Hueneme	2020	0.94
Port Hueneme	2021	0.95
Port Hueneme	2022	0.96
Port Hueneme	2023	0.97
Port Hueneme	2024	0.99
Port Hueneme	2025	1.00
Port Hueneme	2026	1.02
Port Hueneme	2027	1.03
Port Hueneme	2028	1.05
Port Hueneme	2029	1.07
Port Hueneme	2030	1.08
San Diego	2000	1.05
San Diego	2001	1.04
San Diego	2002	1.03
San Diego	2003	1.02
San Diego	2004	1.02
San Diego	2005	1.01
San Diego	2006	1.00
San Diego	2007	0.90
San Diego	2008	0.86
San Diego	2009	0.69
San Diego	2010	0.74
San Diego	2011	0.81
San Diego	2012	0.88
San Diego	2013	0.97
San Diego	2014	1.07
San Diego	2015	1.18
San Diego	2016	1.29

San Diego	2017	1.41
San Diego	2018	1.50
San Diego	2019	1.60
San Diego	2020	1.68
San Diego	2021	1.78
San Diego	2022	1.88
San Diego	2023	1.99
San Diego	2024	2.11
San Diego	2025	2.25
San Diego	2026	2.38
San Diego	2027	2.52
San Diego	2028	2.69
San Diego	2029	2.87
San Diego	2030	3.04
South Coast	2000	0.73
South Coast	2001	0.77
South Coast	2002	0.81
South Coast	2003	0.86
South Coast	2004	0.90
South Coast	2005	0.95
South Coast	2006	1.00
South Coast	2007	0.91
South Coast	2008	0.88
South Coast	2009	0.71
South Coast	2010	0.77
South Coast	2011	0.84
South Coast	2012	0.92
South Coast	2013	1.03
South Coast	2014	1.13
South Coast	2015	1.26
South Coast	2016	1.38
South Coast	2017	1.52
South Coast	2018	1.63
South Coast	2019	1.75
South Coast	2020	1.85
South Coast	2021	1.97
South Coast	2022	2.09
South Coast	2023	2.22
South Coast	2024	2.37
South Coast	2025	2.53
South Coast	2026	2.69

South Coast	2027	2.86
South Coast	2028	3.06
South Coast	2029	3.27
South Coast	2030	3.48

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